Potable water and sanitation in Tenochtitlan: Aztec culture

J.E. Becerril and B. Jiménez

Universidad Nacional Autónoma de México, Instituto de Ingeniería, Apdo Postal 70472, 04510 Coyoacan, Ciudad Universitaria, Mexico D.F. (E-mail: *JBecerrilB@iingen.unam.mx*; *bjimenezc@iingen.unam.mx*)

Abstract A source of clean drinking water is essential, and the Aztecs were quite advanced in providing it. While London still drew its drinking water from the polluted Thames River as late as 1854, the Aztecs brought potable water to Tenochtitlán from springs on the mainland by means of the aqueduct built by Nezahualcoyotl between 1466 and 1478. A second aqueduct was constructed in 1,499–1,500 by the ruler Ahuizotl when the first aqueduct became inadequate. Although the Aztecs had no citywide drainage system, and much of the wastewater ended up in the lake surrounding the city, they had a system to handle human waste by means of privies in all public places and many private dwellings from which excrement was collected in canoes. The excrement was applied as fertilizer to chinampas (floating parcels of land) or sold in the market to be used for tanning animal hides. Urine was collected in pottery vessels to be used later as a mordant for dyeing cloth. The Tenochtitlán environment was obviously healthy for its time, especially in comparison to European cities. Public and personal hygiene contributed to minimize the incidence and severity of illnesses.

Keywords Aztecs; Mexico city; sanitation; wastewater; water

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Introduction

The knowledge of works executed by the Aztecs is based on data provided in the old codices, the traditions written by the first historians of the 16th century, together with the ruins of constructed works which still exist today. The water and intelligent handling of it helped Tenochtitlán to become one of the great political, religious and economic centres of Mesoamerica. It helped the Aztecs to intensify the production of food, and so to increase population and commerce and to maintain a privileged class dedicated to the development of sciences and the arts.

Mesoamérica is designated as the centre-southeastern region of Mexico, and the northern zone of Central America, where the most important pre-Hispanic civilizations bloomed. There was Teotihuacan, the Mayans in the Yucatan Peninsula, as well as the Toltecas and Aztecs on the plateau. Nowadays we have testimonies to their culture and greatness, through the ruins of their ancestral cities. The Aztec culture, contrary to the other civilizations of Mesoamerica, began something late in its cultural ascent, probably toward the year 1325 AD., when they settled down in the Lake of Texcoco, and began construction of the city of Tenochtitlán, today the city of Mexico. The Aztecs had been a warring and nomadic tribe of hunters and gatherers, from the semi-arid region of the north of Mexico. In the following centuries and until the arrival of the Spaniards, they dominated the neighbouring towns and they built a vast empire (Bribiesca, 1958).

Tenochtitlan was one of the last cities of pre-Hispanic Mexico and lasted only two hundred years due to the conquest of the Spaniards. The Aztecs in their passage to the plateau assimilated the technological know-how of many of the towns through which they passed, including those which were already vacated (Teotihuacan and Tula). All this knowledge was used to help found the Mexica seat. From the word Mexitl, one of the

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names of the God Huitzilopochtli, comes the name Mexico. The intensification of agriculture, the creation of new cultivable grounds and the ease of transport, favored the urbanization of population. The economic and demographic power in the valley of Mexico, combined with a military political organization closely related to the hydraulic organization, allowed the Aztecs to dominate the populations and the resources of neighbouring valleys. Water was a strategic element in war and a factor of domination that the Aztecs used to control supply and to maintain government over the region. The hydraulic systems in the lacustrine zone used the same technology as other similar hydraulic works. Examples include dykes and "albarradones" (docks), works of control of floods and drainage, construction of artificial land for agriculture and for living, fresh water conduction by means of channels, drains and aqueducts, and the formation of lagoons and artificial wetlands (León Portilla, 1961).

Climatic and hydrologic conditions

The Valley of Mexico is a closed river basin. As a result, at the heart of the valley there appeared an extensive system of shallow lakes, of lagoons and marshes, formed by pluvial precipitations, the original permanent rivers, mainly from the Sierra Nevada, and many springs. The waters did not get to completely fill the low part of the river basin. A combination of infiltrations, and the intense evaporation characteristic of the region, limited the growth of the lacustrine zone (Figure 1).

The lakes, lagoons and marshes covered about 1,000 km^2 at the beginning of the 16th century. The pluvial precipitation within the valley is concentrated in a single irregular rainy season that is also very unpredictable in terms of its geographic distribution.

Figure 1 The lacustrine river basin of the Valley of Mexico

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Brief history of the Aztecs

Tenochtitlan was one of the last cities of pre-Hispanic Mexico that lasted only 200 years due to the conquest of the Spaniards. The Aztecs in their passage to the plateau assimilated the technological knowledge of many of the towns through which they passed, including those already vacated (Teotihuacan and Tula). This knowledge was essential in the founding of the Mexica seat. The name Mexico possibly originates from the name of Mexitl, the name of the God Huitzilopochtli. At the time when Tenochtitlán was taken by the Spaniards the city was a square of 3 km with a suburban area of 1,000 hectares. This area was a geometric network of streets lined with small houses and religious centres, all set basically around two central places, the Great Temple (Templo Mayor) and the great seat of Tenochtitlán (Figure 2). Roads and bridges were constructed to connect the diverse districts that had grown up on a number of small islands. Chinampas (floating parcels of land, Figure 3) were constructed, first for cultivation and then as the city grew, to provide land on which to construct houses of "adobe" (earth and lime) (Chávez, 1994).

The roadways used to unite the islands served simultaneously as docks and sometimes had floodgates built into them to control water levels. These roads were the main axes; one went from north to south binding Tepeyac, Tlatelolco, Tenochtitlán and Coyoacán; the other from east to west marked by Tlacopan and the centre of Tenochtitlan. The city to the east was limited by a lake, making it necessary to use canoes to arrive at Texcoco. To the south the Iztaplapa road was constructed where the lake was deeper.

Aztec agriculture was based on the culture of "chinampas", an intensive agricultural system of high productivity formed by a succession of constructed high fields on the bed of the lake that formed a complex network of channels (described often as "floating gardens"). Harvested aquatic plants and extracted sediment from the channels were deposited onto the high fields. This system of "chinampas" proved to be a very efficient way of recycling nutrients that had leached from the fertile grounds of those fields. Abundant harvests were produced which satisfied the necessities of the inhabitants of the river basin (Ezcurra *et al.*, 2006).

The greatest challenge for agriculture and the cultures of the valley was management of the lacustrine system. Chinampas arose that extended to the fresh water lagoons of Chalco and Xochimilco, covering most of their surfaces. The lacustrine system, on the other hand, provided a solution in the valley of Mexico to one of the critical problems

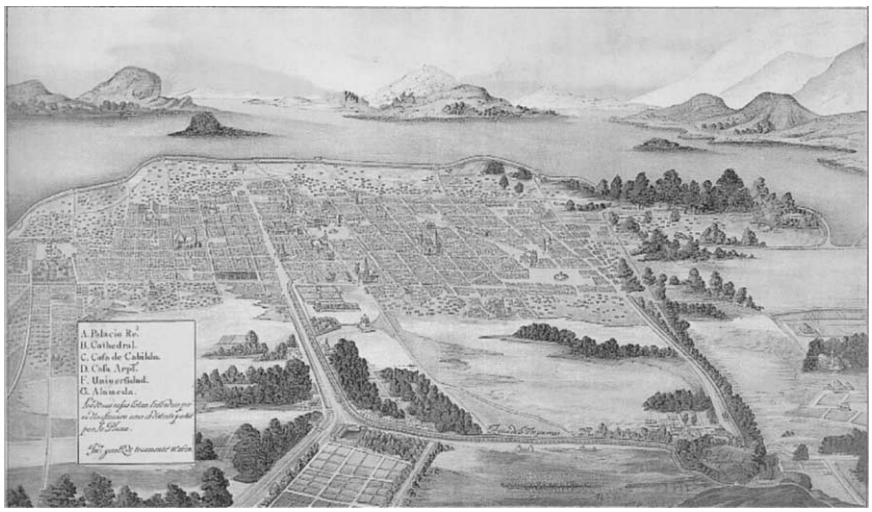

Figure 2 Tenochtitlán City

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Figure 3 Present day view of the Chinampas in Mexico City

faced by Mesoamericans cultures, that of transport. These civilizations did not have animals to carry heavy burdens and did not make practical use of the wheel. They depended on man power, except where transport over water, including lakes, rivers and the sea were possible. The lacustrine system of the valley was criss-crossed by a network of channels and deep drains, most constructed artificially, around which an enormous number of canoes circulated.

The original lakes with the construction of roads and avenues were transformed into several lakes between which there were engineering installations for the control of floods and lacustrine transport. In addition, the hydraulic system functioned such that salinization of the chinampas was avoided. On the other hand, the geographic location of Tenochtitlán gave rise to frequent flood that continued until the middle of the 20th century (Departamento del Distrito Federal, 1976).

Aztec deities of the water

For the Aztecs, Tláloc, wizard and God of the water was adored since he represented the God of water, rain and storms. Tláloc was a benevolent God, but also feared for his multiple expressions by way of floods, drought, hail and rain. These were reasons to keep him content through sacrifices and prayers. One can imagine him with a large headdress, with a type of double fan made of bark paper, and his face covered by a mask formed by ring (serpents) around the eyes and eyeteeth of vipers leaving his mouth. The serpents simultaneously represented lightning and water. The Priest or "Prince Wizard" was called to him. He summoned the clouds shaking his "sonaja", forcing them to meet around the summits of the mountains. Tláloc was also the God of agriculture (Figure 3).

At Tenochtitlán, in the pyramid of the Teocalli there were two elevated sanctuaries of equal importance: the red temple of Huitzilopochtli and the white and blue temple of Tláloc. The feminine deity of water was Chalchiutlicue, the sister or wife of Tláloc (Figure 4). She was the goddess of the seas, the lakes, springs, and torrents and her representation was a tail or a current of blue water and she trailed in her clothes the lunch or "itacate" of a merchant, a warrior and a young woman, symbolizing wealth, power, and beauty. She was worshipped in the springs, rivers and the constructions that supplied the water, where the products of water such as flowers and jewels were offered to him as well as human sacrifices and animals. She lived alongside Tláloc in Tlalocan, in the high mountains. Tláloc, the God of water, had tiny assistants called Tlaloques that were invisible to the human eye. They had watering cans in their hands and obeyed the orders of Tláloc; with wooden clubs they could produce claps of thunder (Chávez, 1994).

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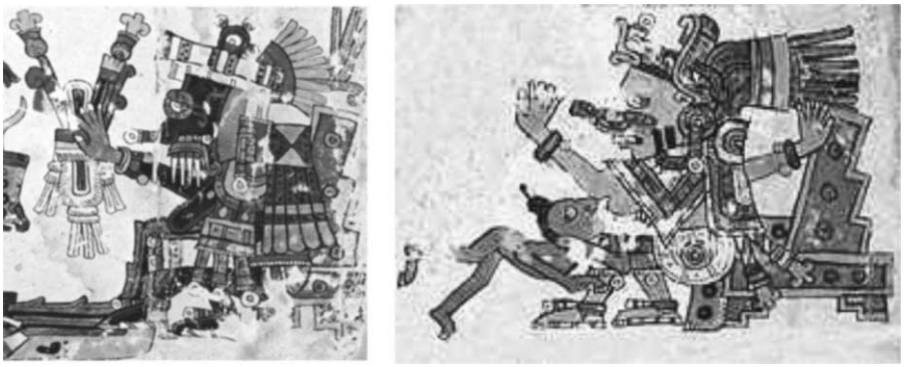

Figure 4 Representation of Tláloc (right) and Chalchiutlicue (left)

On the other hand, the garden paradise of the God of rain, the Tlalocan, was opened to those who died by drowning, killed by lightening or any accident or disease attributed to the water. Those that died in this way were considered as chosen by their God and were envoys to the always green and humid paradise.

Potable water supply

Tenochtitlán did not lack the precious necessary liquid for life, assured then by the pure waters of the lagoon and by some springs that appeared in small barren islands. For example there was a sacred spring in the ceremonial center, Tozpálatl and that according to tradition was the place where the city was initially founded. Water for daily domestic consumption was initially carried in wide "cantaros" (mud containers) and stored in bathtubs, until engineering advances permitted the construction of aqueducts. This supply was precarious but safe and was the first stage in the development of Tenochtitlán.

The first attempt to bring water from the springs of Chapultepec towards Tenochtitlán was made by constructing a sewer with stakes, reeds and mud, but because of the low resistance of the materials it wasn't very effective.. The historian Gomara related that "although it is built on water, they do not take advantage of that water to drink, but bring water from a source in Chapultepec, by two sewers each one as fat as an ox". When one sewer is dirty, they divert the water into the other so that they can clean it. From this source they filled the reservoirs, pools that were used for washing, and provided the water for many houses. People paid for the right to take water from the reservoirs, collecting it using canoes (Palerm, 1990). Still, this sewer fed buildings by means of aqueducts and was used to supply a basic underground distribution system for pools and gardens. It also fed the botanical gardens and the city enjoyed a great number of adorned green areas with flowers.

The springs were property of the town and administered by the Government, who determined the use, and handling of the water. The entire town had the obligation to cooperate in any way that the authorities indicated for the accomplishment of hydraulic works. Gradually one went away forming in the city which would be a complex and magnificent system or network of aqueducts by where the potable water arrived. Often of joint way to these systems of pick up and it empties of the water, were constructed roads that connected to the most important cities of lake. Two aqueducts constructed with stuccoed mud tubes brought potable water to the center of Tenochtitlán: one came from Chapultepec and the other of Churubusco. The distribution of waters in the city became by sources and pools, but only the palaces and houses of the noble had their own takings.

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The town in general obtained them through canoes that filled in the bridges of the aqueduct, in where also were men who by payment filled the canoes. The potable water necessities, in fact, were few, since they were only used to drink and to bathe, because for the irrigation of chinampas and gardens water of the drains was used (Musset, 1992).

Aqueducts

The emperor Chimalpopoca realized that the growth of the city, on the one hand, had almost exhausted the springs and, on the other hand, the Aztec activities were contaminating the lagoon; for these reasons, he decided to bring water from Chapultepec (using an aqueduct). Extensive knowledge of construction techniques and ingenuity were needed to build the first aqueduct of Chapultepec. It was 12 km in length, 7 m wide and brought water from Chapultepec to the Templo Mayor. Unfortunately it was worn away little by little by its own waters, since it was constructed of mud.

Almost 30 years after its construction, the aqueduct of Chapultepec was totally destroyed by the great flood of 1449. Nezahualcóyotl, constructed a second aqueduct on the same outline as the previous one. This time much more resistant materials were used, like lime, stone and rubblework; it was so well built that with some small repairs it continued giving service until years after the arrival of the Spanish conquerors.

Ahuizotl, the governor in 1499, decided to bring more water from five springs in Coyoacán. The water of the springs was caught by means of a dam whose construction followed the line of the road from Xochimilco. A mud sewer was constructed and it completed a network of distribution from springs and streams with underground connections for temples and palaces. In addition, spillways or garbage dumps were built to direct to the channels the excess of water that came by the conduit, but conserving such amount of it that when arriving at the last storage tank, in Pahuatlán, where the city finished, it had sufficient height and volume to produce a great roar with its fall. In 1500 a catastrophic flood, the product of rain that lasted more than forty days and culminated with a whirlwind, destroyed the work (Lombardo de Ruíz, 1973). The aqueduct was described in 1520 by Hernán Cortés (conqueror of Tenochtitlán):

> Along one of the causeways to this great city run two aqueducts made of mortar. Each one is two paces wide and some six feet deep, and along one of them a stream of very good fresh water, as wide as a man's body, flows into the heart of the city and from this they all drink. The other, which is empty, is used when they wish to clean the first channel. Where the aqueducts cross the bridges, the water passes along some channels which are as wide as an ox; and so they serve the whole city. Canoes paddle through all the streets selling the water; they take it from the aqueduct by placing the canoes beneath the bridges where those channels are, and on top there are men who fill the canoes and are paid for their work.

Sanitation

The city was kept very clean. Streets in every quarter were swept and watered daily by a thousand public employees. Personal cleanliness and hygiene were valued highly by the Aztecs, as suggested by many references in early sources to soaps, deodorants, dentifrices, and breathe fresheners. Rubbish was incinerated due to a lack of disposal sites. In fact, rubbish was burnt as a fuel and to provide illumination as a public service. The biodegradable rubbish was buried in the patios of houses, used by animals and if there was a lot, shipped to the mainland for disposal.

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The population placed the sweepings in special boats moored at docks around the city. The sweepings were sold as soil amendments in Tlateloco, and apparently included excrement. Mixtures of sweepings and excrement were also used to fertilize the chinampas or to bolster the banks bordering the lake. Urine was collected in containers in all houses to be used in combination with mud as a fabric dye.

The city gave great importance to sanitary and environmental control. The house of Moctezuma Ihuilcamina, called Teocalli had three patios; one of which had a source to distribute water to all the building. In addition each room had a bath (Figure 5). In the main seats of Tenochtitlán and the market, there were public pools that were cleaned by underground water-drainage and there were pipes filled with water brought from Chapultepec, probably for the cleaning of clothes. In the Chapultepec forest there was a great lake near the springs and a great well on the hill. The lake was used for water storage, and was the start of the distribution system (León Portilla, 2001). In addition, the Aztecs had steam baths called temascales (Figure 5), which were very low small closed houses, in whose interior ten people could fit either lying down or seated. Steam was produced by adding stones that had been heated in a furnace to a small amount of water.

The Spanish conquerors were amazed at how often the Aztecs bathed, in contrast to European practice. Moctecuhzoma bathed twice a day, and everyone bathed often. Several drains crossed the city from west to east, emptying into the lake at Texcoco. All had floodgates that allowed drainage of water in the mornings and prevented access of waters from the lagoon to the city during the afternoon. There were also pipes which discharged the waste waters of the city, but without solid wastes, which were deposited in special depots and later used in the agriculture systems.

The sanitary problem seemed to be well controlled, since excrement and organic detritus were not allowed in the drains, but were stored in special places to be used later to improve soils. Many historians have admired the cleaning of the city, probably when comparing it with the conditions of health and sanitation, not very adept, which existed in European cities at the time. Due to its location, lower than the rest of the lakes, Tenochtitlán was exposed to great floods, the reason why the Aztecs took on the task of controlling the level of water in the lakes, turning aside the rivers and currents, initiating the system of water-drainage that took five centuries to perfect. The native population was basically healthy, due to good nutrition, relative freedom from epidemic pathogens, and sound public sanitation. However, dampness and pollution of the lakes did promote dysentery, rheumatism, and respiratory infections (Ortiz de Montellano, 1990).

Figure 5 Ruins of the baths of Moctezuma

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Conclusions

The lacustrine civilization of the Aztecs achieved important technological and cultural developments that helped them to optimize their resources and adapt to the adverse conditions of the river basin. These advances were lost after the Spanish conquest because the lacustrine surface was considered incompatible with the introduced methods of construction and land use. In order to protect the city of Mexico from the risk of floods and from drying out of the muddy subsoil of the old bed of the lake, drainage works of greater and greater size and complexity were constructed and as consequence these works later produced changes in the environment of the river basin. The progressive disappearance of "chinampas" (an efficient and sustainable agricultural system) was one of the first consequences. As a result of this transformation, the expert ways of handling water applied by the Aztecs were modified drastically. This has created an imbalance in the hydrologic cycle of the river basin whose adverse effects, such as floods, exhaustion and contamination of the aquifer, and differential sinking of the ground, are still being felt today in the valley of Mexico.

Even though Aztecs had no drainage system, and wastewater ended up in the lake surrounding the city, they collected human waste and transported it in canoes to be used as fertilizer in agricultural fields or sold in the market to as tanning animal hides. Urine was also collected to be used later as a mordant for dyeing cloth. Since this time, Aztec recognized the importance of recycling nutrients and compounds contained in wastewater.

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